

## Research Highlight

Cloud-resolving and large-eddy simulation results are often used to inform convective parameterization development for climate models simply owing to the fact that, in theory, all aspects of a simulated system are known. However, high-resolution model simulations contain a variety of complex dynamical structures that often do not map directly to the structural elements of convective parameterization. An example is updraft convective mass flux, among the most fundamental of convective parameterization elements. On the face of it, all vertical winds are known in a cloud-resolving model simulation; some are upward and some are downward. However, the presence of gravity waves in stable atmospheric layers introduces oscillations in vertical motion that do no transport and thus should be neglected in parameterization of convective fluxes. And gravity waves are common in the vicinity of the convection that triggers them. However, they are not simple to filter from a continuous field of motion. Using an isentropic analysis technique, this study demonstrates how vertical motions in a high-resolution simulation can be partitioned into gravity wave and convective draft motions, and how microphysical processes can be examined within the context of identified convective updrafts.

For this study we analyze 10-minute 3D output fields from a previously documented day-long simulation of a mesoscale convective system observed during the TWP-ICE campaign. The simulated field is first divided into convective and stratiform regions of precipitation. Each region is then sorted into bins of equivalent potential temperature by height, and the isentropic mass flux within each bin is defined based on the mean motion within that bin. In so doing, oscillating motions within a bin cancel one another. Figure 1 demonstrates that isentropic mass fluxes are substantially lesser than traditionally calculated Eulerian mass fluxes at all elevations within both regions. Especially large apparent contributions from gravity waves are seen in the upper troposphere, associated with atmospheric stability, but large apparent contributions are also seen within the atmospheric boundary layer. It is trivial to extend this technique to analysis of microphysical quantities, such as hydrometeor number concentrations and mass mixing ratios. For example, Figure 2 demonstrates application to snowflake number concentrations and mass mixing ratios. In the most undiluted updrafts (at highest equivalent potential temperature), snowflake number concentration and mixing ratio monotonically increase up to elevations of roughly 12 km; overshoots carry substantial mixing ratios but fewer numbers. Such analysis provides a tool for examining microphysical evolution within the context of convective parameterization for advancing understanding of complex updraft properties. Process rates and other such quantities can be similarly analyzed.

Using an isentropic analysis of convective mass fluxes that filters gravity waves from simulated fields yields substantially lower mass fluxes than a traditional Eulerian analysis. Updraft and downdraft mass fluxes are reduced symmetrically at each elevation, and the calculated ratio of downdraft to updraft mass flux (a specified value in some convective parameterization schemes) is also increased, by roughly one-third on a vertically integrated basis, from 0.6 to 0.4 in the simulation analyzed here. An extension of the approach to analysis of microphysical quantities is suited to examining changes in microphysics within coherent updraft elements as a function of height and dilution, either for inclusion within convective parameterization or for the purposes of advancing understanding of a system in which many processes are closely coupled with dynamics.

## Reference(s)

Mrowiec AA, OM Pauluis, AM Fridlind, and AS Ackerman. 2015. "Properties of a mesoscale convective system in the context of an isentropic analysis." *Journal of the Atmospheric Sciences*, doi:10.1175/JAS-D-14-0139.1. ONLINE.

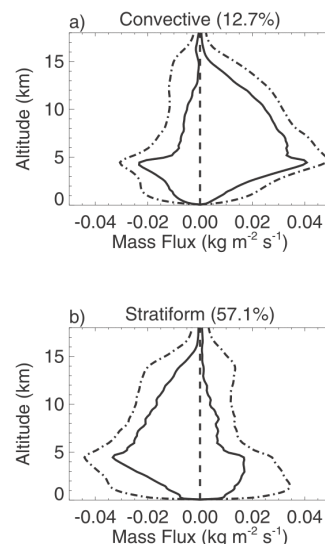


Figure 1. Isentropic (solid) and traditional Eulerian (dash-dotted) upward and downward mass fluxes.

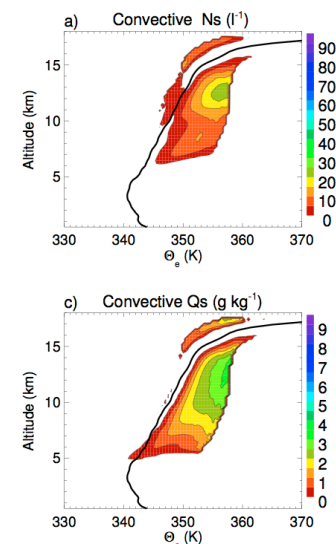


Figure 2. Snow number concentration ( $N_s$ ) and mass mixing ratio ( $Q_s$ ) in regions identified as convective.

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## Working Group(s)

Cloud-Aerosol-Precipitation Interactions